Linking Short And Long Term Sediment Delivery To Morphology And Seascape Evolution Of Continental Margins

James P.M. Syvitski
INSTAAR Univ. of Colorado,
Boulder CO, 80309-0450
phone: (303) 492-7909 fax: (303) 492-6388 email: james.syvitski@colorado.edu

Mark D. Morehead
USDA-ARS, Northwest Watershed Research Center,
800 Park Blvd., Plaza IV, Suite 105, Boise, ID 83172;
phone: (208) 422-0719, fax: (208) 334-1502, email: mmorehea@nwrc.ars.pn.usbr.gov

Award No: N00014-95-1-1281
ASSERT: N00014-96-1-0994

LONG TERM GOALS

Develop numerical models useful for the simulation of sediment delivery and accumulation on continental margins over time scales of tens to thousands of years. Model predictions will help us understand the evolution of bedding architecture and sediment characterisitcs on continental margins through sea level fluctuations, climate change, and other relevant environmental factors. ONR interests include the development of a numerical predictor of the acoustic signature of remote margins based on a region's geological history.

OBJECTIVES

1) Is the variability in a river's sediment load, observed over the last 100 years or less, adequate to provide a proxy for longer-term climate trends driving most rivers through the Holocene period?
2) Will only the most exceptional hyperpycnal flood events make it across the Eel shelf before losing their driving force?
3) What are the causes and attributes of rating hysteresis (i.e. rising limb of a river's flood wave being able to carry more sediment than the falling limb)?
4) Do complex sea level fluctuations on an active margin control the pattern of sedimentary deposits?
5) Can 2D-SEDFLUX simulate the laboratory deposits created by the St. Anthony Fall's Hydraulic Laboratory using their Jurassic Tank setup?

APPROACH

• Task B3) Sediment Delivery Model: Develop a model of how sediment is delivered to, and accumulates on, a continental slope. Predict delivery to the shelf-slope break from fluvial point and line sources. Compare open-slope sediment delivery (distributed) with canyon-fed delivery (localized).

• Task B8) Seascape-Stratigraphic Model: Model major influences (climate, sea-level, tectonics) on processes that control slope morphology, stratigraphy, and acoustic realizations. Model(s) to include the effects of: a) external forcing mechanisms; b) short-term and long-term delivery of sediment; c) 2-

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302 Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE **Linking Short And Long Term Sediment Delivery To Morphology And Seascape Evolution Of Continental Margins**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Colorado at Boulder,INSTAAR,Boulder,CO,80309**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

D simulations of individual mass movements (submarine slides, debris flows and turbidity currents); d) excess pore pressure on slope failure.

WORK COMPLETED

1) Simulated the Eel River (CA) discharge through the transition between ice-age climate and Holocene climate, over a 2500 year period. Simulated the Kliniklini River (BC) discharge over the last 10,000 years along with another 2000 years into the future.
2) Simulated the development of a hyperpycnal plume developing from an exceptional (1995) flood event of the Eel River, and flowing out and across the Eel Margin under different alongshelf current scenarios.
3) Examined the impact of hysteresis on the sediment delivery through a river's flood wave, with particular reference to the Eel River margin.
4) Applied a modified HYDROTREND sediment delivery model to two giant rivers (Liard and Mackenzie rivers, NWT).
5) Modified and applied 2D SEDFLUX to Jurassic Tank experimental set up conditions.
6) Completed the proto-version of the 3D SEDFLUX model architecture.
7) Categorized the morphologic variability of siliciclastic passive margins.
8) Used Brownian motion theory to simulate the avulsion of river channels across a river delta plain.

RESULTS

- The river basin discharge simulator (HYDROTREND) has been modified to simulate the rain-flood dominated hydrology of the Eel River, the snow-melt dominated hydrology of the Mackenzie River of Arctic Canada, and the glacier-melt dominated hydrology of the Klinaklini River (BC). The model accurately produces the modern flood frequency discharge curve and the sediment rating curve of the Eel River indicating and can realistically simulate the supply of water and sediment to the Eel margin. Furthermore, HYDROTREND has been shown to produce discharge and sediment load time-series, which are statistically similar to measured data for the Mackenzie and Klinaklini Rivers indicating the model is generally applicable to a wide variety of river basins with varying climatic and geologic conditions.
- An integrated set of model runs (HYDROTREND, PLUME and SEDFLUX) have been conducted to investigate the preservation potential of various modes of river discharge (flood dominated versus steady discharge) and the effects of climate change on the resulting sedimentary deposits. Results show the complex interplay between the frequency and size of discharge events with the frequency and magnitude of ocean storm events controls the preservation potential of individual floods. Model runs of climate change scenarios have shown climate signals preserved in the sedimentary record. However a regional analysis of the sedimentary sequences is often needed to faithfully reconstruct past climate, due to the varying preservation potential caused by distance from the river mouth, flood size and frequency and storm size and frequency, all of which change through time.
- Recent modeling efforts suggests that sediments may be reaching the Northern California Slope not only by surface plumes, but also periodically by hyperpycnal flows. The hyperpycnal flows will deliver sediment to the Eel Canyon, and when there is an alongslope current, northward to the Humboldt Slide area and possibly beyond to the slope gullies. Such flows would act as a line source from which multiple fingers of the flow could form simultaneously and accelerate down the continental slope, causing erosion where the seafloor is steepest and deposition where it levels out.

Over geologic time, these flows may be a major source of sediment to the slope, augmenting the sediment delivery from plumes during river flooding. The episodic turbidity currents coupled to more ambient plume sedimentation can work together to shape the seafloor and develop landward migrating (antidunal) bedforms. Such deposits are common over turbidite channel levees and near the base of continental slopes such as in the Humboldt Slide area.

- Various models have been examined that purport to capture the variability in sediment load for a given discharge level for a particular river. The time variability of sediment load appears dependent on the river basin characteristics, the climate regime, and the time scale of interest. For example, annual variations in sediment load are consistent with climate change on sediment concentration.
- Based on numerical experiments, small basins are able to capture in terms of textural proxies, both the natural variability associated with precipitation and temperature as well as realistic scenarios of abrupt climate change. Open ocean basins, like the Eel River, are less likely to record the proxy record of ambient climate variability, since the natural climate variability is strongly dominated by infrequent and large events that do not track climate events.
- In an effort to predict the flux of sediment to the ocean for ungauged and prehisotric rivers and at the dynamic level (daily), a new method has been developed for predicting a rivers' rating curve based on basin moorphology and climate.
- 2D-SEDFLUX is able to simulate the sediment architecture produced by the St. Anthony Falls Hydraulics Laboratory. The model also was able to simulate the movement of the shoreline during changes in base level (sea level).
- To provide the Navy with spatial seafloor properties, the multiprocess SEDFLUX model is being converted to a full 3D seascape evolution model. The code is presently able to handle complex topography, multiple rivers, sealevel fluctuations, plumes and diffusion routines. Plans are underway to add 3D slope stability, with subsequent debris flow and turbidity current routines.
- The basic morphology of a continental passive margin is dependent on the margins' underlying strata architecture, terrestrial sediment flux and the degree of submarine canyon incision. For example low slope margins are sediment supply dominated with few canyons; steep and rough margins are supply limited, having many canyons.
- The position of the main distributary of a delta plain channel appears to be a stochastic Brownian process with a Gaussian distribution over short time scales. These predictions are largely independent of the avulsion physics.

IMPACT/APPLICATIONS

Key insights have been gained on:

- the spatial and temporal variability of the sediment flux from rivers,
- the effect of climate change of the sediment and water flux from rivers,
- how the river derived sediment is dispersed by plumes and initially deposited along a coastline,
- and how the complex interaction of the sedimentary processes combine to create the final sedimentary sequences.

Developed models have been used to simulate the sedimentation patterns occurring during the last glacial maximum and during present climate conditions and to compare them with sequences observed through geophysical records on the Eel Margin. The model runs compare remarkably well with the observations confirming our ideas of the changing preservation potential of flood deposits as flood and storm magnitude and frequency change.

We are on the path to predict acoustic properties of the seafloor of continental margins, based on process-based modeling and remote data input (i.e. satellites). Such models offer the possibility of making predictions where field data is limited. The impact of natural events (floods, storms) on the acoustic character and features of continental margins can now be examined. SEDFLUX model is becoming an integral part of the reservoir characterization effort of MOBIL Technology Corporation. HYDROTREND and PLUME are models being used by Raytheon-Hughes Corporation to fuse environmental data records (infrared and visible wavelengths) downloaded from satellites for the purpose of natural disaster mitigation efforts. A white paper is in place that would allow INSTAAR numerical models, such as HYDROTREND and PLUME to link with a variety of DSMP satellite data with other NOAA-generated microwave-meteorological models to provide environmental predictions in aid of the health of our coastal zone. New efforts related to mine counter measures (MCM) and antisubmarine warfare (ASW) will profit greatly from these modeling and data assimilation efforts.

TRANSITIONS

Model runs of the Eel River Margin are available to STRATAFORM participants. Mike Steckler (LDEO) is working on scaling issues related to SEQUENCE and SEDFLUX model results. New releases of INSTAAR models have been transferred to MOBIL Technology Center. We have helped Lincoln Pratson (Duke U.) develop a 1D Lagrangian turbidity current model (1D BANG). Jasim Imran (U. South Carolina) has provided us with the counterpart 1D non-steady Eulerian code so that we might undertake a direct comparison with the Lagrangian model. Our seismic simulator (ECHO) has been modified and used in cooperative work with St. Anthony Falls Hydraulic Lab's flume efforts and Duke University (Pratson). We are working with H. Lee on implementing earthquake accelerations into our failure criteria in 2D SEDFLUX, the seascape-evolution model.

RELATED PROJECTS

- MOBIL Technology Center (Cullick, Sarg, Gouveis,) supported INSTAAR efforts (Bahr, Pratson, Hutton, O'Grady) to develop a data base on continental margin morphology, sedimentology, oceanography and tectonics. Parameters are being linked into super-variables to determine the effective influence of past history, ocean energy, seismic energy and sediment delivery on continental margin morphology and deposit architecture. The two STRATAFORM margins are included in the data base.
- Work with G. Parker, C. Paola (U. Minnesota), P. Heller (U. Wyoming), L. Pratson (Duke U.) in developing a continental margin experimental tank, through the support of a NSF grant and consortium support of oil companies (MOBIL, EXXON, TEXACO, CONOCO, JAL). It is anticipated that one of the experimental runs would be on a STRATAFORM margin.
- Raytheon-Hughes has linked with the INSTAAR modeling efforts to use STRATAFORM and or other models for the development an algorithm related to fuse satellite data (infrared and visible wavelengths) and provide information on littoral sediment transport.

PUBLICATIONS

Wang Y., Ren, M.-e and J.P.M. Syvitski. 1998. Sediment Transport and Terrigenous Fluxes. In: K.H. Brink & A.R. Robinson (editors) The Sea: Volume 10 - The Global Coastal Ocean: Processes and Methods. John Wiley & Sons, New York, p. 253-292.

Mulder T., Savoye B., Syvitski, J.P.M. and Piper, D.J.W. 1998. The Var Submarine Sedimentary System: understanding Holocene sediment delivery processes and their importance to the geological record. In M. S. Stoker, D. Evans, A. Cramp (editors): Geological Processes on Continental Margins: Sedimentation, Mass Wasting and Stability, Geol. Society, Spec. Publ., London, 145-166.

Syvitski, J.P.M., Morehead, M. and Nicholson, M. 1998. HYDROTREND: Simulation of trends in river discharge and sediment transport from climate normal and GCM predictions. Computers and Geoscience v. 24(1): 51-68.

Hill , P.; J P Syvitski, R D Powell, E A Cowan.1998. Floc settling velocities under a buoyant discharge plume in Glacier Bay, Alaska. Marine Geology v.145 (1-2): p. 85-94.

Syvitski, J.P.M., Nicholson, M., and Skene, K., Morehead, M.D.1998. PLUME1.1: Deposition of sediment from a fluvial plume. Computers and Geoscience, v. 24(2): 159-171.

Skene, K., Piper, D.J.W., Aksu, A.E., and Syvitski, J.P.M. 1998. Evaluation of the global oxygen isotope curve as a proxy for Quaternary sea level by modeling of delta progradation. Journal of Sedimentary Research, 68: 1077-1092.

Syvitski, J.P., 1998. The link between abrupt climate change and basin stratigraphy: A numerical approach. International Conference of Recognition of Abrupt Climate Change in Clastic Sedimentary Environment: Methods, Limitations and Potential. Program and Abstracts, June 8-10, 1998, Stockholm, Sweeden, p. 11-13.

Syvitski, J.P. and Morehead, M.D., 1999. River predictions for oceanographers and paleocean-ographers: Application to the Eel River Margin, N. California. Marine Geology, 154: 13-28

Morehead, M.D., and Syvitski, J.P., 1999. River Plume Sedimentation Modeling for Sequence Stratigraphy: Application to the Eel Shelf, California. Marine Geology 154: 29-41.

Perlmutter, M.A., DeBoer, P.L., and Syvitski, J.P. 1999. Geological Observations and Parameterizations.In: J.W. Harbaugh, L.W. Whatney, E. Rankay, R. Slingerland, R. Goldstein, and E. Franseen (eds.) Numerical Experiments in Stratigraphy: Recent Advances in Stratigraphic and Computer Simulations. SEPM special publication. No. 62. (in press)

Syvitski, J.P.M., Pratson, L. O'Grady, D. 1999. Stratigraphic Predictions of Continental Margins for the Navy Parameterizations.In: J.W. Harbaugh, L.W. Whatney, E. Rankay, R. Slingerland, R. Goldstein, and E. Franseen (eds.) Numerical Experiments in Stratigraphy: Recent Advances in Stratigraphic and Computer Simulations. SEPM special publication. No. 62. (in press)

Azetsu-Scott, K., and Syvitski, J.P.M. 1999. How melting icebergs influence particle distribution in the water column. Journal of Geophysical Research, 104: 5321-5328.

Bahr, D., Hutton, E.W.H., Syvitski, J.P., and Pratson, L. (in press) Compaction: a theoretical analysis from first principle. Computers & Geosciences.

Pratson, L., Imran, J., Parker, G., Syvitski, J.P., Hutton, E. (in press) Debris flow versus turbidity currents: A modeling comparison of their dynamics and deposits. AAPG Special Publication. Ed. A. Bouma.

Pratson, L., Imran, J., Hutton, E., Parker, G., Syvitski, J.P., (in press) BANG1D: A one-dimensional, lagrangian model of turbidity current mechanics. Computers and Geosciences.

Syvitski, J.P., and Hutton, E.H., (in press) 2D SEDFLUX 1.0C: An advanced pocess-response numerical model for the fill of marine sedimentary basins. Computers and Geoscience.

Conference Abstracts & Proceedings

Syvitski, J.P., Hutton, E. W.H., Morehead, M.D., Pratson, L., O'Grady, D., Bahr, D., Sarg, R. 1998. Numerical Tools for Stratigraphers. SEPM-IAS Research Conference: "Strata and Sequences on Shelves and Slopes, Sept. 15-19, Sicily, Italy, p. 110.

Pratson, L., Gouveia, W., Courtney, R., Syvitski, J.P., Paola, C., and Parker, G. 1998. Constraining the stratigraphic information content of seismic data. SEPM-IAS Research Conference: "Strata and Sequences on Shelves and Slopes, Sept. 15-19, Sicily, Italy, p. 85.

Bahr, D.B., and Syvitski, J.P. 1998. Predicting compacted sediment porosity profiles. Proceedings of IAMG'98 The fourth annual conference of the International Association of Mathematical Geology. Eds. A. Buccianti, G. Nardi, and R. Potenza. De Frede Publishing. 627-632.

Syvitski, J.P., 1998. Understanding Sedimentary Processes and Palaeoenvironments in Fjords: A Personal 25-Year Journey, In: International Workshop on Sedimentary Processes and Paleoenvironment in Fjords, University of Tromso, April 22-24, 1998, p. 31-33.

Syvitski, J.P., Meade, R.H., and Bobrovitskaya, N.N. 1998. Water and sediment discharge dynamics of Russian Arctic rivers. Program and Abstracts of the 28th Arctic Workshop, March 12-14, 1998. p. 145-148.

Mulder, T., Savoye, B., Piper, D.J.W., Parize, O., and Syvitski J.P.M. 1998. Hyperpycnal plumes associated with various sediment transport processes at the mouth of the Var River (French Mediterranean). Their importance in the sedimentary record. SEPM-IAS Research Conference: "Strata and Sequences on Shelves and Slopes, Sept. 15-19, Sicily, Italy. p. 79.

Mulder, T., and Syvitski J.P.M. 1998. Hyperpycnal activity and global sediment delivery at river mouths. Their change with sea level. SEPM-IAS Research Conference: "Strata and Sequences on Shelves and Slopes, Sept. 15-19, Sicily, Italy. p. 78.

Syvitski, J.P., and Morehead, M., 1998. The link between abrupt climate change and basin stratigraphy: A numerical approach. AGU 1998 Fall meeting EOS suppliment, v. 79 (No. 45), p. F467.

Morehead, M.D., Syvitski, J.P., Bahr, D., Mulder, T. 1998. A first step at determining the controls on the sediment rating coefficients. AGU 1998 Fall meeting EOS suppliment, v. 79 (No. 45), p. F291.

Syvitski, J.P., Hutton, E.H. and Pratson, L. 1998. Numerical simulation of debris flows and turbidity currents with longterm feedback from evolving boundary conditions AGU 1998 Fall meeting EOS suppliment, v. 79 (No. 45), p. F330.

Morehead, M.D., and Syvitski, J.P. 1998. The ABCs of a river's sediment load: Predicting the rating coefficients. Rocky Mountain Hydrologic Research Center. 53rd Annual Meeting, Aug. 28, 1998, Boulder, Co., Meeting Program and Abstracts p. 14.

Pratson, L., Gouveia, W., Courtney, R., Syvitski, J.P., Hutton, E., Paola, C., and Parker, G. 1998. Constraining the stratigraphic information in seismic reflection data. AGU 1998 Fall meeting EOS suppliment, v. 79 (No. 45), p. F468.

Syvitski, J.P., Powell, R., Parker, G., Elverhoi, A., Pratson, L. (1998) SSN Geophysical Surveys of Arctic Continental Margin Slopes: An Opportunity. Arctic Ocean Science from Submarines — A Report Based on the SCICEX 2000 Workshop, Applied Physics Laboratory, Univ. of Washington p. F40-F41.